SIMULATION ON ATKINSON-MILLER CYCLE ENGINE OF FOUR STROKE TWO-WHEEL VEHICLE FOR LIGHT OPERATING CONDITION

SOBANA RAJ SUBRAMONIAN

UNIVERSITI SAINS MALAYSIA

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by

SOBANA RAJ SUBRAMONIAN

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LIST OF ABBREVIATIONS

AFR or A/F Ratio	Air Fuel Ratio
BDC	Bottom Dead Center
BSFC	Brake Specific Fuel Consumption
cc	Cubic Centimeter
CO_2	Carbon Dioxide
EEVO	Early Exhaust Valve Opening
EIVC	Early Intake Valve Closing
H_2O	Hydrogen Dioxide
LEVO	Late Exhaust Valve Opening
LIVC	Late Intake Valve Closing
NO_x	Nitrogen Oxides
O_2	Oxygen
OEE	Over Expanded Engine
PISO	Pressure-Implicit with Splitting of Operators
PPM	Parts Per Million
RON	Research Octane Number
RPM	Revolution Per Minute
SIMPLE	Semi-Implicit Method for Pressure-Linked Equations
SIMPLEC	SIMPLE Consistent
TDC	Top Dead Center
UDF	User Define Function

LIST OF SYMBOLS

Symbol	Definition	Unit
C_v	Specific heat value	kJ/kg K
G_f	Fresh gas percentage	
k	Specific heat ratio	
M_t	Total mass	
M_f	Fuel mass	
M_a	Air mass	
M_{ex}	Exhaust Gas Mass	
N	Revolution per second	rev/s
n	Number of revolution per cycle	
P	Pressure in the cylinder	kPa
R	Gas constant	kJ/kg K
R_e	Expansion ratio	
R_c	Compression ratio	
T	Temperature in the cylinder	K
V_d	Displacement volume	m^3
V_c	Clearance volume	m^3
V_{exp}	Expanded volume	m^3
W	Work	kJ/kg
X_r	Residual gas percentage	
Subscript		
1,2,3,4	Label on p-V diagram	
do, co	Volumes of Otto cycle	
dm, cm	Volumes of Miller cycle	

SIMULASI KITAR ENJIN ATKINSON-MILLER DALAM ENJIN EMPAT LEJANG KENDERAAN DUA RODA UNTUK PENGOPERASIAN RINGAN

ABSTRAK

Enjin asal motosikal adalah berdasarkan pada kitar Otto. Enjin kitar Otto hanya menggunakan kuasa yang dihasilkan dengan efisien pada keadaan pengoperasian kenderaan yang berat seperti berat keseluruhan maksimum, tekanan tayar yang rendah dan luas kawasan rintagan yang maksimum. Hasilnya, kuasa maksimum ini telah dibazirkan untuk pengoperasian ringan. Disebabkan oleh strok lejang kuasa yang agak terhad dalam kitar Otto, haba yang diperoleh tidak dapat digunakan sepenuhnya. Justeru, haba yang masih terdapat di kebuk pembakaran disingkirkan melalui ekzos dan sistem penyejukan enjin. Tetapi, aplikasi kitar enjin Atkinson-Miller dengan nisbah mampatan yang tinggi dapat menyelesaikan masalah ini. Objektif analisis ini adalah untuk menyiasat hasil yang diperoleh daripada aplikasi kitar enjin Atkinson-Miller dengan nisbah mampatan yang tinggi pada enjin motosikal. Penyelidikan ini melibatkan analisis satu dimensi yang menggunakan perisian Ricardo WAVE untuk memperoleh data supaya kelebihan dan keburukan aplikasi nisbah mampatan yang tinggi pada enjin petrol kitar Atkinson-Miller boleh diramalkan. Selanjutnya, analisis tiga dimensi dilakukan dengan menggunakan perisian ANSYS Fluent untuk menjalankan siasatan terutamanya ketukan enjin yang berlaku disebabkan oleh tekanan mampatan yang tinggi. Selain itu, simulasi tiga dimensi dapat meramalkan ketumpatan gas, tekanan gas dan suhu gas. Didapati bahawa, kehilangan haba melalui blok enjin dan ditambah pula dengan gas ekzos yang bersuhu tinggi disinkirkan melalui ekzos mengurangkan keseluruhan kerja bersih dan kecekapan haba. Jumlah haba yang disingkirkan melalui ekzos oleh enjin kitar Atkinson-Miller adalah kurang berbanding enjin kitar Otto disebabkan oleh strok

lejang kuasa yang lebih lama. Walaubagaimanapun, penggunaan konsep enjin kitar Miller dalam enjin kitar Atkinson-Miller, menyebabkan enjin mengalami kemerosotan dalam kuasa brek, kuasa tork dan kecekapan terma brek. Oleh itu, kuasa brek dan tork yang rendah adalah kelemahan yang dikesan pada enjin kitar Atkinson-Miller tetapi, kuasa brek dan tork meningkat secara drastik selepas nisbah mampatan enjin ditingkatkan kepada 20:1. Namun sedemikian, analisis tiga dimensi mendapati enjin kitar Atkinson-Miller mengalami masalah ketukan enjin bagi nisbah mampatan melebihi 11:1. Aplikasi enjin kitar Atkinson-Miller sahaja tidak mencukupi. Tetapi, dengan nisbah mampatan sehingga 11:1, enjin kitar Atkinson-Miller mempunyai keupayaan pada penggunaan bahan-api dengan efisien untuk pengoperasian ringan seperti berat keseluruhan yang minimum, tekanan tayar yang optimum dan luas kawasan rintangan yang minimum. Didapati bahawa, aplikasi enjin kitaran Atkinson-Miller (10 darjah LEVO dan 15 darjah LIVC) pada nisbah mampatan 11:1 (A10M15_RC11) mengurangkan penggunaan bahan api sebanyak 1 peratus pada pengoperasian ringan dan 5 peratus pada pengoperasian yang berat pada corak pemanduan di pinggir Bandar dan luar Bandar. Untuk corak pemanduan di lebuh raya, penggunaan bahan api dikurangkan sebanyak 2.9 peratus hingga 3 peratus pada keadaan pengoperasian yang ringgan dan berat. Walau bagaimanapun, kitaran enjin A10M15_RC11 mengalami kadar pemindahan haba yang tinggi semasa lejang mampatan dan pembakaran dalam enjin jika dibandingkan dengan enjin kitar Otto tetapi mempunyai kadar pemindahan haba yang rendah semasa lejang kuasa dan ekzos yang mengurangkan suhu gas semasa lejang masukan. Kesimpulannya, kitar enjin A10M15_RC11 mempunyai kecekapan terma brek yang tinggi dan penggunaan bahan api yang rendah pada keadaan pengoperasian ringan dan berat.

SIMULATION ON ATKINSON-MILLER CYCLE ENGINE OF FOUR STROKE TWO-WHEEL VEHICLE FOR LIGHT OPERATING CONDITION

ABSTRACT

Standard engine found in motorcycles are based on Otto cycle. The Otto cycle engine utilize the maximum amount of power is found to be efficient only at heavy operating condition such as maximum total mass, low tire pressure and maximum drag due to maximum frontal area. Consequently, this maximum power has been wasted for the light operating condition usage. Due to short expansion stroke in the Otto cycle, the system was unable to fully utilize the heat generated. Hence, extra heat has been ejected to the environment through the exhaust and engine block cooling system. However, the Atkinson-Miller cycle engine application with higher compression ratio is able to solve the problem. The objective is to investigate the behavior of the Atkinson-Miller cycle spark ignition engine with high compression ratio of a motorcycle engine. This research involves one dimensional analysis using Ricardo WAVE to find the engine output data and the advantage and disadvantages of having high compression ratio of the Atkinson-Miller cycle spark ignition engine can be predicted. Further to this, three dimensional analysis is performed using ANSYS Fluent to conduct the investigation mainly on fuel knocking due to high compression pressure. The three dimensional simulations predict on the gas density, gas pressure and gas temperature profile. It has been found that, an increase in the heat flux through engine block coupled with high temperature exhaust gas exiting the exhaust port consequently decreases both total net work output and the thermal efficiency. The amount of heat ejected through the exhaust is lower in the Atkinson-Miller cycle engine compared to the Otto cycle engine mainly due to the greater expansion. However, with the application of the Miller cycle concept in the over expanded cycle,

the engine experiences losses in brake power, brake engine torque and brake thermal efficiency. The low torque and lower brake power is found to be downside of this Atkinson-Miller cycle engine but, the brake power and torque drastically improved after engine compression ratio increased to 20:1. However, three dimensional analysis of the Atkinson-Miller cycle found the engine to experience fuel knocking for compression ratio above 11:1. Consequently, the stand alone operation of Atkinson-Miller cycle is insufficient. Therefore, the Atkinson-Miller cycle engine are coupled with high compression ratio, 11:1. The high compression ratio Atkinson-Miller cycle engine has improved fuel consumption for light load/operating condition (minimum total mass, optimum tire pressure and minimum drag due to minimum frontal area). The Atkinson-Miller cycle engine (10 degree LEVO and 15 degree LIVC) at compression ratio of 11:1 (A10M15_RC11) reduces fuel consumption by 1 percent at light load and 5 percent at heavy load condition for suburban and urban drive pattern. For highway drive pattern, fuel consumption reduced by 2.9 to 3 percent for both load condition. However, A10M15_RC11 cycle engine experiences high heat transfer rate during compression stroke and combustion compared to the Otto cycle engine but has low heat transfer rate during power and exhaust stroke which reduces intake gas temperature. This situation concludes that, A10M15_RC11 cycle engine has low fuel consumption and high brake thermal efficiency for both load conditions.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Petrol price goes up every year due to increasing demand for petrol. For developing countries, personal vehicles such as motorcycles and cars are preferred due to a lack of proper public transportation (Pongthanaisawan & Sorapipatana 2010). Hence, as shown in Figure 1.1, total number of vehicles increases approximately by 43 percent from year 2005 to 2008 and expected to increase approximately by 46 percent from year 2008 to 2015 in ASEAN countries.

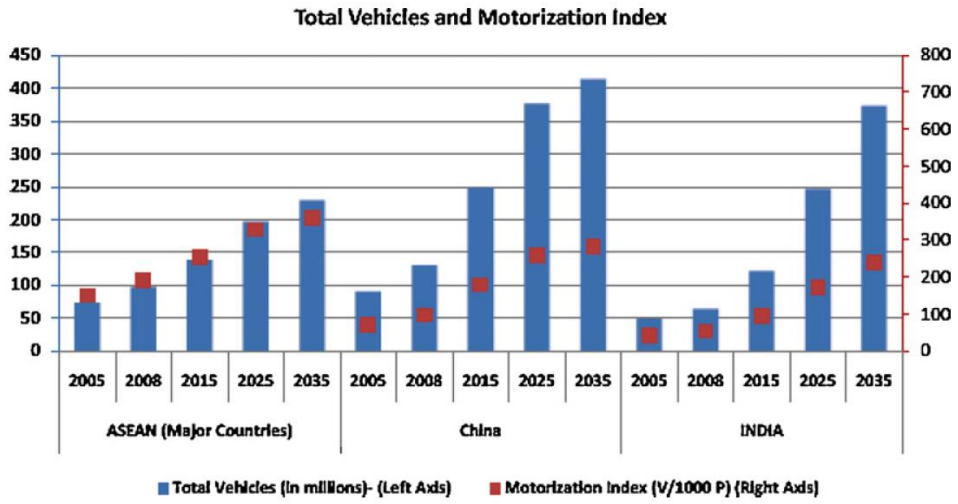

Figure 1.1: Total Vehicle and Motorization index in ASEAN, China and India (Silitonga et al. 2012)

Among the personal vehicles, motorcycles are most favored in developing countries due to vehicle ownership cost and high petrol price. Besides owning cost and petrol price, maintenance cost is another reason as motorcycles exhibit lowest maintenance cost compared to cars (Chiun et al. 2009). Malaysia and Thailand have highest user of motorcycles compared to other developing countries. Shown in Figure 1.2, total number of motorcycles are approximately equal to the total number of cars

in Malaysia. Total number of motorcycles are accounts for 49.76% of total numbers of vehicles in Malaysia, raised the awareness to improve the inefficient four stroke motorcycle engines that are carbureted, small scaled and low tech (Jih Houh 2012).

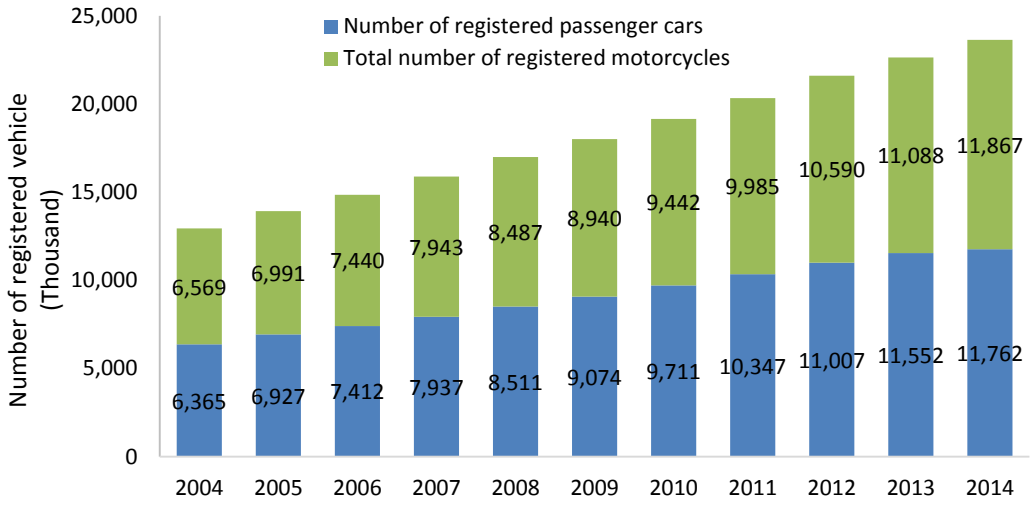

Figure 1.2: Motorcycles and car ownership in Malaysia (Asean Japan Transportation Partnership 2014)

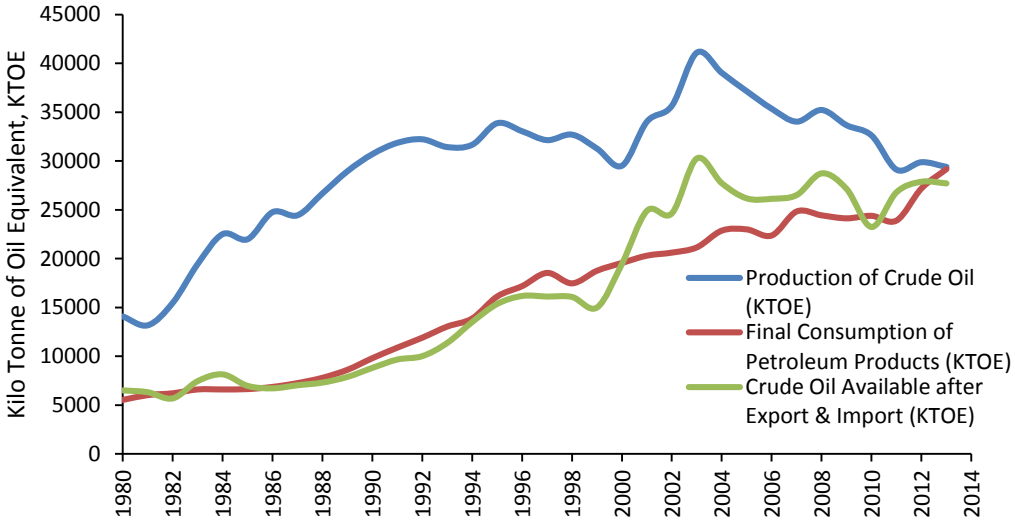

Figure 1.3: Final consumption of Petroleum Products and Crude Oil production in Malaysia (MEIH 2011)

As shown in Figure 1.3, increase in vehicle ownership increases final consumption of petroleum products in Malaysia and the trend increases every year but crude oil production in Malaysia reduces after year 2003. Moreover, petrol price increases due to total world crude oil consumption exceeds the production and found